DARWIN—REMOTE ACCESS AND DATA VISUALIZATION ELEMENTS

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Abstract

NASA Ames Research Center is using information systems technology for developmental aeronautics to redefine the classic wind-tunnel test. The project, called Developmental Aeronautics Revolutionizing Wind-tunnels with Intelligent Systems of NASA (DARWIN), combines custom and commercial software and hardware and advanced experimental instrumentation to create an extended version of the Remote Access Wind Tunnel system. With DARWIN, aeronautics test results are produced and made available to industry and researchers faster, cheaper, and better. This paper will provide details of the DARWIN remote access systems, software developments, and future plans.

Introduction

Traditionally, a wind-tunnel test requires bringing the group of technicians and engineers to a single location. The engineers, needed for their expertise, must travel to the test site to have access to the data. Gathering the results of the test and interpreting the data is time consuming and can take up to six months. By the time the data reaches aerospace researchers or industry customers (Boeing, McDonnell Douglas, etc.), the results often indicate valuable insights and areas that could have been explored during the test if better knowledge had been immediately available.

In 1994, NASA Ames Research Center prototyped a system known as the Remote Access Wind Tunnel (RAWT) system.[1] RAWT was a Silicon Graphics Inc. (SGI) Indy™ workstation using SGI's InPerson™ collaboration software. InPerson™ permits the use of a shared whiteboard and access to an attached digital camera for video conferencing over a network. What was unique about the RAWT systems was their placement and connections. One SGI was placed in the NASA Ames' 11-Foot Wind Tunnel, another was in Seattle, Washington, at Boeing Aircraft, and yet another was in Long Beach, California, at McDonnell Douglas.

RAWT was connected via NASA's AEROnet. AEROnet is a closed point-to-point restricted network designed to support high bandwidth, cross country connections to NASA's Numerical Aerodynamics Simulator (NAS) supercomputers. AEROnet personnel arranged for a dedicated link from the Ames 11-Foot Wind Tunnel to the existing AEROnet links to Boeing and McDonnell Douglas. RAWT gave the remote industry engineers access to their counterparts in the wind tunnel at Ames and enabled real-time discussion and collaborations about test decisions and data results.

For the RAWT system, AEROnet also provided specialized access to one the NAS's Cray super-computers. This enabled complementary computational fluid dynamic (CFD) codes to be initiated from the wind tunnel. The results from the CFD were then compared to data from an advanced experimental technique called pressure sensitive paint (PSP).[2] The project that created RAWT and supported the remote wind tunnel tests was called IofNEWT (Integration of Numerical and Experimental Wind Tunnels).[1]

DARWIN[3] is the direct successor to IofNEWT and RAWT. The DARWIN Integrated Product Team (IPT) was formally created at NASA Ames in March of 1995 with the express purpose of extending and generalizing the IofNEWT and RAWT systems to develop prototype systems and architectures to support remote aeronautics services. DARWIN has also significantly extended the paradigm for remote aeronautics test operations.

Where IofNEWT and RAWT were developed for a unique wind tunnel test, the DARWIN remote access system is designed to simultaneously support multiple combinations of any type aeronautics test (i.e. flight tests, wind tunnel tests, CFD series, or flight simulations). DARWIN has also specifically addressed deficiencies in the original RAWT operational model. RAWT was required to have a dedicated operator in order to allow any remote access to data. If the operator was not available at the wind tunnel to operate the

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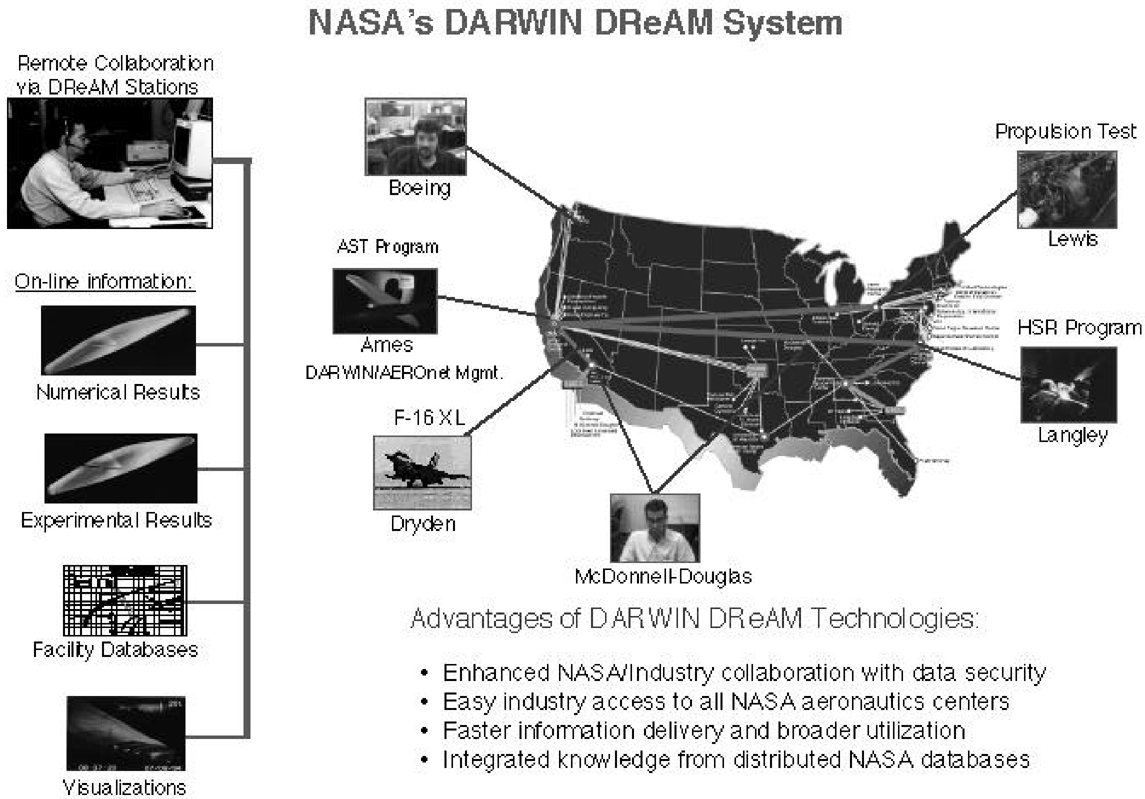

Figure 1
NASA's DARWIN Information System

InPerson™ software and explicitly pass information to the remote users then the RAWT system was unusable. Additionally any data that was shared with the remote sites were static images of the PSP pictures or the plots captured from another source. No raw data was actually accessible until well after the test run was complete. The DARWIN remote access system solves these issues and provides an unparalleled capability for remote data access and analysis. This turns aeronautics testing into a dynamic collaborative process enabling better, interactive research.

DARWIN DReAM System

The DARWIN remote access and data visualization elements are integrated into the Distributed Remote Access Machine (DReAM) System (Figure 1). This consists of the DARWIN Workspace environment, the client systems at the remote user sites, the DReAM servers in the aeronautics test facilities (wind tunnels, flight control rooms, etc.) and the central DARWIN Server. These systems are all connected utilizing DARWINnet at Ames (described in a later section) and AEROnet for national connectivity. The rest of this paper describes the various components and supporting elements of the DARWIN remote access portion of the overall DARWIN information system.[3]

The remote access software is based on a three-tier client/server/server architecture (Figure 2). The first server is the DARWIN Server, running a secure HTTP (hypertext transport protocol) server, the supporting central executive server software, and the DARWIN meta-atabase.[4] The third tier server is the DReAM server which is hosted in the aeronautics test area of choice. The remote DReAM client system hosts the DARWIN Workspace environment that is composed of a secure HTTP browser, an executive, and a tool kit of additional visualization and collaboration software. Initialization and startup of all remote processes on the ServIO[4] system, DReAM server, and DReAM client is done via the secure HTTP links. Many of the small remote applications are written in Java or JavaScript as remote agents that are either executed or started by the client's browser. The larger applications, such as the collaboration whiteboards, remote video tools, and higher end data visualization tools are authorized and

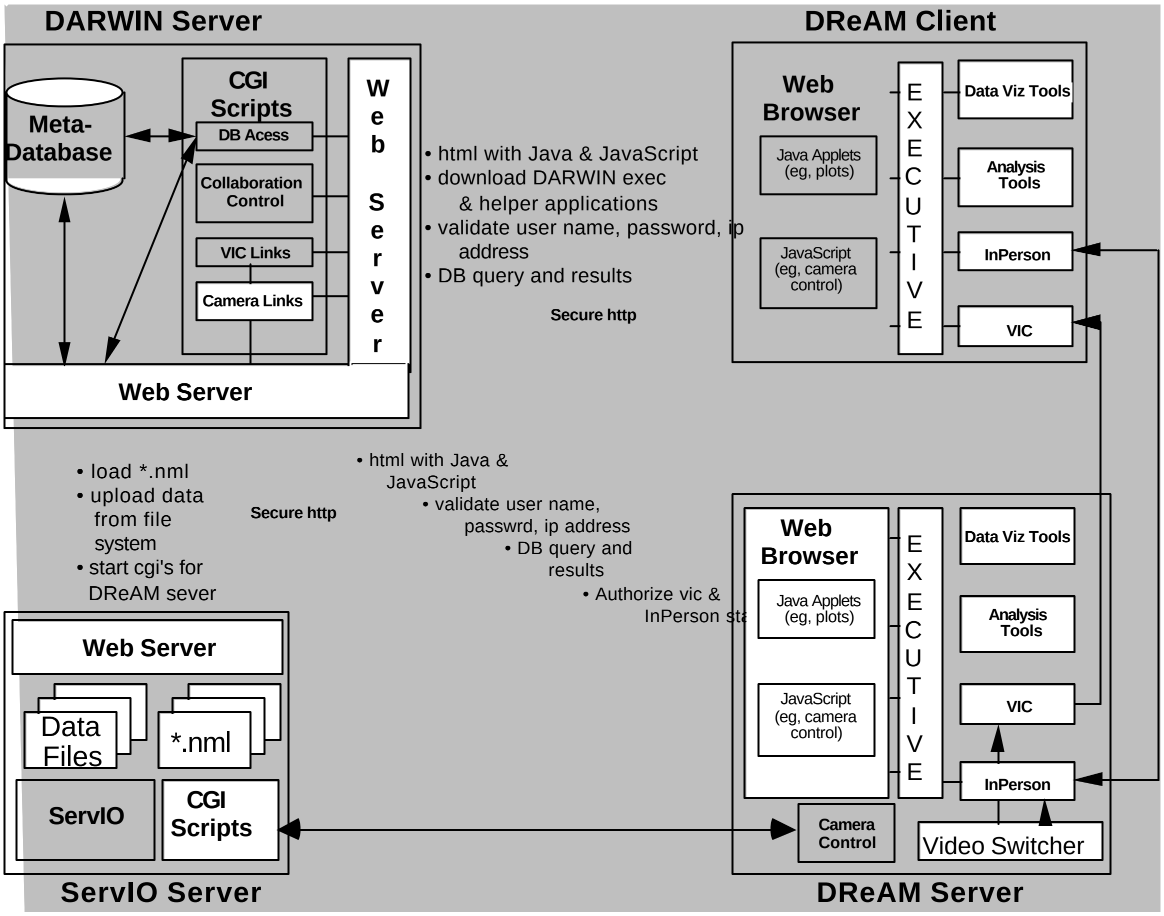

Figure 2
DARWIN DReAM Software Process Model

initiated by the executive software on the client or through the DARWIN server.

DReAM client and server

The DReAM client and/or server is an SGI Indy™ workstation with a digital video and audio system to permit remote collaboration. The video conferencing software allows researchers to communicate timely results to aerospace industry customers, as well as interact remotely with other NASA engineers on-site. The DReAM server in the wind tunnels will also be connected to a computer controlled video switcher to allow multiple cameras to show different views of the wind tunnel, the models, and the various control systems. DReAM systems will host the DARWIN Workspace environment, any future CFD tools, and additional data visualization extensions that are developed as well.

DARWIN Workspace environment

The DARWIN Workspace environment controls user authentication and privacy, data security, advanced video and interactive conferencing tools, remote control of cameras, interactive database access, and new custom tools for data visualization and analysis. The framework for the DARWIN Workspace environment is composed of a HTTP browser, specifically Netscape Navigator™ 2.x, that can display HTML (hypertext markup language) "pages" (containing text, JavaScript code, and Java applets), the DARWIN executive software, and a tool kit of supporting software applications. The browser, the executive, and the tool kit applications are all resident on the customer's workstation. The HTML pages, which can be static documents or the dynamic results of CGI (common gateway interface) PERL scripts or JavaScript functions, are retrieved from the DARWIN Server via secure HTTP over the DARWINnet and AEROnet communications network.

The DARWIN executive software provides the communication link between the web browser and the specialized data analysis tools. The executive software is written in PERL, Java, and JavaScript embedded in HTML. These cross-platform interpretive languages are easily understood and provide a simple way to distribute a cross-platform graphical interface tool built upon an HTTP browser. The executive's role is to coordinate the browser-related applications and the additional visualization and collaboration tools. The executive sends signals to the browser telling what information pages it should be displaying and coordinates the signals sent to the server-side and the client collaboration tools.

To access data from a particular wind tunnel test, a DARWIN user logs in to the system by selecting the test hyperlink from the DARWIN server and then entering a user name and password. The internet protocol (IP) address of the requesting computer is also checked against a list of allowed machines before access is granted. Once logged in to the DARWIN system, the user is presented with links to the tests that he/she is permitted to review. The front page for a wind tunnel test typically contains a summary of the test's purpose, statement of progress, access to the test engineer's log, and various views on the data collected, such as a listing of the latest runs from the wind tunnel as shown in Figure 3. All of this is dynamically generated on the DARWIN Server from the information available in the meta-database.

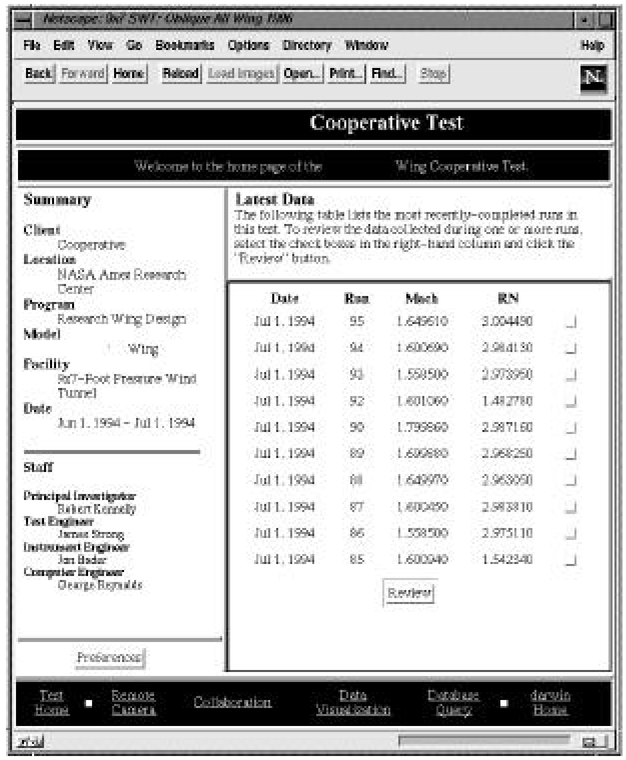

Figure 3
DARWIN Workspace Test Screen

The DARWIN Workspace environment can directly display or plot most of the raw data files in the DARWIN database file system. The browser's point-and-click interface will allow the user to interrogate specific runs by querying appropriate meta-data and then automatically retrieve and present the information. Dynamic plots of the data are generated using a graph package written in Java (Figure 4). The linkage between the information presented and the related data sets is the enabling factor in being able to dynamically access the data and generate knowledge from the test.

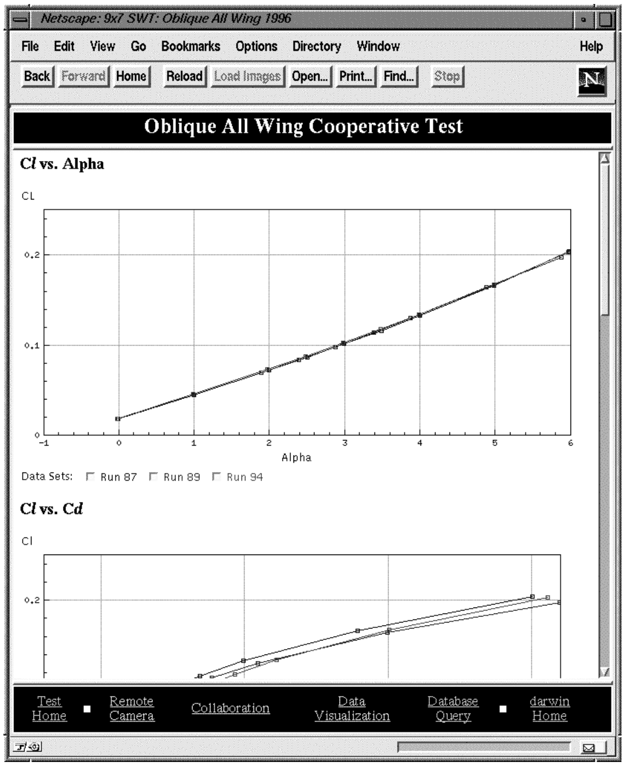

Figure 4

DARWIN Workspace Java Graphs

For in-depth analysis, more complex manipulation of the files is required than the browser-based applets can provide for evaluating and interpreting the data. The DARWIN Workspace environment enables an intelligent data-visualization element that incorporates and presents the information from the database. The executive is capable of automatically extracting meta-data information and properly passing the information directly to remote data visualization tools.

Currently several specialized software programs are bundled with the DARWIN Workspace environment to aid in analysis of particular types of data files. One example is Greenboot, which is a data analysis software package for interpreting pressure sensitive paint (PSP) images. DARWIN users may view PSP images directly in the web browser, but if they want to manipulate the image, subtract another image from it, or perform detailed investigation of a particular region of the image, then they can use Greenboot for the task. To use Greenboot, the user selects a hypertext link with a Greenboot extension. The DARWIN executive requests the location of the PSP files from the database, loads the files via the DARWIN Server, launches Greenboot on the user's machine, and then directs Greenboot to load the files.

When *a priori* complementary CFD data exist to match the conditions from an expected experimental test, it is included the data sets loaded into the database. The DARWIN Workspace will then provide access to that data as well. The meta-database will be queried to provide the location of the desired files and then the browser may present the information as static images or the executive will launch the appropriate data visualization tool. A first generation tool for this purpose, called ExViz (experimental visualization tool) is being developed by the NAS in support of DARWIN. This extensibility of the DARWIN Database and the Workspace environment will allow full comparisons of different instrumentation suites, and cross comparisons between experimental and numerical test results.

The use of collaboration software to share and edit documents has proven invaluable in aiding remote discussion and sharing of data during a wind tunnel test. Proprietary whiteboards like SGI's InPerson™ support both high quality graphics and text. Recently, InPerson™ has been released also as a Windows™ application for Intel-based computers. While this particular release only addresses a limited set of the wind tunnel users, the movement to cross-platform compatibility and interoperability will enable the Workspace tools to be widely available.

A cross-platform digital video tool for DARWIN enables remote collaboration and the dissemination of data amongst the aeronautics test participants. Specific video feeds of different views of the model in the tunnel and the test monitors will provide immediate information about the state of the wind tunnel test. While proprietary tools enable high quality digital video on specific platforms, the wide range of users and participants in the aeronautics tests will require the use of cross platform tools. The tool currently in use in the DARWIN Workspace is called vic (video conferencing tool) from Lawrence Berkeley National Laboratory.[5] Vic has been ported to most UNIX systems, has a beta port to Windows, and compatible tools are being developed for the MacOS.

<u>DARWIN Server</u>

The DARWIN Server is the central point for the DARWIN DReAM system. It manages all access links to the wind tunnel tests, serves interactive web data and applications to the DReAM clients, hosts the database system, and links requests from the DReAM clients to the DReAM data system in the appropriate wind tunnel. The server software has been architected to support multiple, simultaneous aeronautics tests containing secure and proprietary data. A DARWIN administrative setup function exists to permit the configuration and control of the database and DReAM links needed for a given test. The administrative function determines the default preferences and tools used in the DARWIN Workspace and which remotes sites will be supported.

The server will support test specific login names, passwords, and security certificates to ensure that proprietary data is protected. Currently the DARWIN Server is an SGI Challenge S with 12 gigabytes of disk space. The DARWIN Server dynamically generates all of the information presented on the DReAM client based upon the user preferences defined prior to the test and the information stored in the meta-database. The Test Engineer's log, which describes the state of the test and the particular issues associated with the testing and model, is regularly queried from the test managers database and stored in the test meta-database.

Coordination, access, and authorization to all of the database and DReAM test data is controlled from an HTTP (web) server software with custom PERL CGI scripts. Currently the DARWIN Server is using the Netscape FastTrack™ server software, but any secure HTTP server would fill this function. The web server serves as the front end to the DARWIN Database and ServIO data acquisition system. The database and data acquisition design and implementation underpinning the DARWIN remote access system is described in Schreiner, et al.[4]

The DARWIN Server hosts the DARWIN Intelligent Database, which is composed of two parts: (1) the formal database, which contains meta-data sufficient for logical queries and for locating raw data files in (2) the file system, which contains the top level results used for data analysis and design cycle decisions made by the aerodynamicists. Using CGI scripts, the DARWIN web server accesses the database to retrieve the latest wind tunnel data and build up-to-date displays for the user. The user may also customize the display of data by using a form-based interface to specify preferences for what plots should be generated and what columns should appear in the summary tables.

ServIO system

The ServIO system, while not a portion of the remote access system, is the data system that feeds the DReAM system. It functions as the data repository for the test-relevant DARWIN DReAM information and advanced instrumentation data (usually a combined several gigabytes of data) and holds the active data files referenced in the database. The advanced data acquisition and monitoring software, ServIO, collects data from both the traditional wind tunnel data acquisition systems and the advanced experimental systems, such as PSP systems, and advanced microphone arrays.[6] The data acquired by the ServIO system from the instrumentation suites is reduced the ServIO process into namelists that describe the data and its location. These namelists are automatically input into the DARWIN Database. In the current model, the ServIO server is an SGI Challenge S with 10 gigabytes of disk space.

DARWINnet

DARWIN provides remote access to the NASA Ames wind tunnels facilities through a dedicated site-wide fiber optic intranet. The DARWINnet was installed in 1995 to connect all of the aeronautics test related sites at Ames and is closed to non-DARWIN use. It is three pair of 62.5 micron multimode fiber optic cable and three pair of single-mode cable for future growth. This internal network is currently supporting the FDDI (fiber distributed data interface) protocol and is configured to allow bandwidth of 100 megabits per second to all of the aeronautical test facilities at Ames. The DARWINnet is using a star topology of small rings connected to a central hub. FDDI is used between the routers and to the workstations.

From the central hub the connection to industry is provided by the AEROnet nationwide network provided by NASA's Numerical Aerodynamics Simulator facility. AEROnet is composed of dedicated T1 and T3 connections using IP to transfer data to the U.S. aeronautics industry. Only restricted connections to the open Internet are permitted on either DARWINnet or AEROnet.

The DARWIN network is a class B set of IP addresses. This allows DARWIN to provide specific IP ranges for each of the test facilities at Ames (DARWINnet) and to provide DARWIN IP ranges to other NASA centers. Figure 5 shows a NASA-wide conceptual. implementation of the DARWIN network. DARWIN deliberately subnets the network within NASA Ames and each aeronautics test facility to permit the various data acquisition, DReAMs, and advanced experimental instrumentation to operate independently. This network model restricts unauthorized or accidental access between the systems within the test facility and between test facilities.

The use of these isolated networks and subnets are the first level of security that DARWIN provides. User authentication is determined via login names and passwords specific to the industrial partner and the particular test. The machine IP address is also used to authenticate the user and the remote site. Data privacy and security is maintained through the use of separate and secure data channels for each of the wind tunnel tests regardless of the user. The DARWIN Server is the *only* access point for remote systems to access the wind tunnel test data. All data requests are made through the central server and no explicit links between the DReAM server and the DReAM client are made without the DARWIN Server's authorization. Software encryption is used between the DARWIN Server and the DReAM client. Hardware encryption is an option used for very secure tests, but is limited to a maximum of ethernet speeds of about 6–8 megabits per second. Each test user is provided with an encryption certificate or key that is valid for only the specific test. Using all of the different techniques (isolation, authentication, and encryption) DARWIN provides a robust level of security to the data provided to the remote user.

nRAWT Systems

In early 1995, DARWIN was tasked by NASA Headquarters Office of Aeronautics (Code R) to develop and distribute a version of the next generation RAWT system to each of the NASA aeronautic research

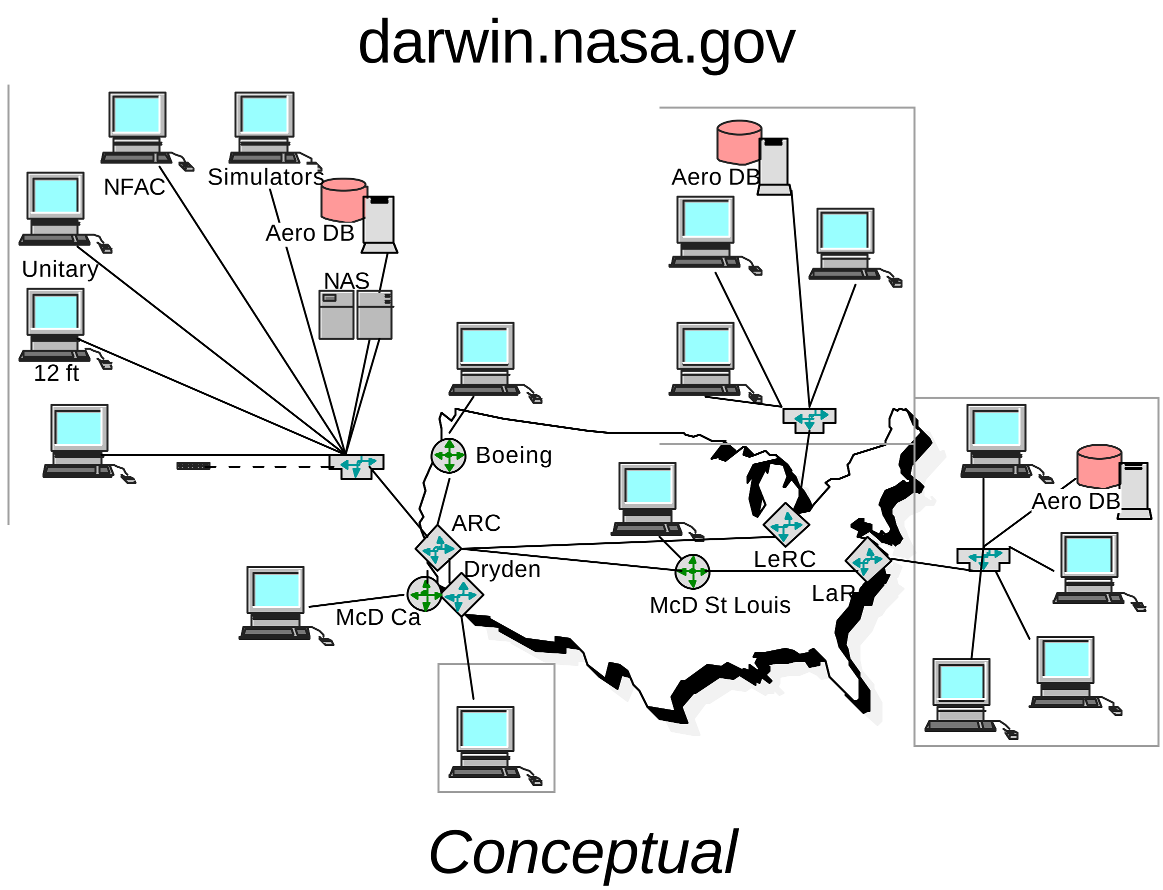

Figure 5
Conceptual DARWIN network

centers. These include NASA's Ames Research Center in Mountain View, CA, Dryden Flight Research Center in Edwards, CA, Langley Research Center in Hampton, VA, and Lewis Research Center in Cleveland, OH. DARWIN has developed multiple next generation RAWT systems (nRAWT) that have been distributed to the other NASA aeronautics centers. These systems were delivered and installed in April and May of 1996. These nRAWT systems can act either as small aeronautics DReAM servers or as DReAM clients. DARWIN nRAWT and DReAM components are very similar. The nRAWT systems have all of the components necessary to connect to the local data acquisition system and the AEROnet. Details of hardware are described below.

nRAWT System Hardware

nRAWT systems are composed of a workstation desk with a rack mount side unit to house the additional nRAWT components. It has been augmented with extra cooling fans, power strips, and the necessary hardware attachments. An SGI Indy™ workstation with a MIPS processor running at 175 MHz is situated on the top. It has no internal floppy disk drive, a 2.0 GB Hard Drive, and a 21 inch Sony Monitor. nRAWT includes a video switcher/router with 10 inputs, a 1200 dpi color laser printer, a FDDI/Ethernet capable router, a small ethernet hub, and a network encryption device. This robust system has been custom developed and packaged to provide the capabilities of a DReAM data server or a DReAM client machine.

The DARWINnet at Ames links together the local facilities permitting remote access. Similar links to the aeronautics test facilities at the other NASA aeronautics centers connect their local versions of the nRAWT system. Certain Centers, such as Lewis, have been independently adapting the early versions of the RAWT concept to support remote access to production test data. NASA Lewis's RACR (Remote Access Control Room) is one such system. Some of the lessons learned from RACR have been integrated into the DARWIN nRAWT system. The primary example of this is the optional use of hardware encryption for the network data. The nRAWT system provided to Lewis is being used as a development system.

DARWIN Remote Access Support

Over the course of the DARWIN project, several opportunities to support and test out aspects of the DARWIN remote access system have arisen. DARWIN has provided the necessary technical assistance to ensure success for all parties involved.

MAPPS test

The purpose of the Microphone Array Phased Processing System (MAPPS) is to provide accurate and detailed maps of acoustic sources for models tested in wind tunnels in a timely manner.[6] MAPPS integrates several instrumentation and computational systems with DARWIN's high speed network systems and super-computing access to produce noise maps at specified frequencies. The signals are measured with a 40-element microphone array mounted in the wind tunnel and processed on a supercomputer. Results of the processing are displayed using a user friendly interface to Ames developed visualization software. The processing of each test point is performed before the next test condition is established. This quick turnaround of data allows the researcher to guide the testing to best make use of the test time available.

The first use of the MAPPS was a test of a 4.7% scale DC-10 model in NASA Ames 40-by-80-Foot Wind Tunnel in August, 1995. The major accomplishments from this test were: (1) the first on-line array analysis for multiple frequencies of acoustic measurements using the DARWINnet supercomputer link; (2) critical identification of acoustic sources from many aircraft components and their relative contribution to noise levels of the aircraft; (3) on-line results for 200 frequencies within time of other measurements during a wind tunnel run. This reduced the processing turn around time from 3 hours to 1/2 hour for one data point. The results helped McDonnell Douglas make better use of the testing time by identifying tonal sources and determining if they were detrimental to the test.

Dryden Flight Research Center Flight Test

DARWIN is currently supporting flight tests of a modified F-16XL aircraft involving real-time data collection and analysis, at Dryden Flight Center in Southern California. The tests, a collaboration between several industry and NASA groups, have focused on supersonic active laminar flow techniques. DARWIN's involvement in supporting this test was setting up the three-way link between the two NASA centers, Dryden and Langley, and the industry partner. The nRAWT machine at Dryden is acting as the DReAM data server, the nRAWT machine at Langley and an Indy™ at the industry site are acting as a DReAM clients. The DARWIN provided hardware encryption units are being used to additionally protect the proprietary data being shipped over the AEROnet. The DARWIN Workspace is not being used for this test.

12-Foot Wind Tunnel High Wing Transport Test

This test in March 1997 is the culmination of the DARWIN IPT's development effort. For this test, the full capabilities of the DARWIN information system will be utilized. The DReAM systems will be at several remote locations around the country at industry and NASA. The DARWIN Workspace will be able to present all data and results within minutes if the data acquisition. The DARWINnet and AEROnet links will be fully optimized to permit high bandwidth remote collaboration and analysis.

Future Development and Plans

The nature of the DARWIN Workspace and the DReAM systems is inherently modular. This enables piecemeal extensions and additions to be added in a timely manner. DARWIN is tracking the rapid industry growth and development in collaboration software and is evaluating and adding these capabilities to the DReAM systems and the Workspace as appropriate.

One distinct possible addition to the DARWIN Workspace is the integration of the CFD Assistant software to initiate CFD runs complementary with the ongoing experimental tests that DReAM system is supporting.

Intelligent System for Simulating Test Results

Typically computational fluid dynamics (CFD) numerical simulations are done well in advance of commencing testing in the wind tunnel. However, situations may arise during a wind tunnel test where none of the numeric solutions done ahead of time adequately models the current wind tunnel conditions. In this case, the test engineer may use NASA Ames' CFD Assistant to help with configuring a flow solver to produce a new simulation and with identifying flow features of the resulting solution file.

Two keys to producing a successful CFD solution are (1) properly configuring the input files and (2) understanding the domain of applicability of the solver code. The input advisor portion of the CFD Assistant checks the wind tunnel conditions proposed for the simulation and informs the user of whether the solver code is capable of producing a physically valid solution for the given situation. If the code is appropriate, then the necessary input files are generated and configured automatically so that the engineer does not have to bother with details of file formatting and naming conventions required by the solver.

Once the solver has produced a solution, the test engineer can use the CFD Assistant's feature extractor component to check for expected flow features such as shocks or vortices. Algorithms for detecting these features are captured by the program so the test engineer does not need to know the details of how a CFD expert would go about detecting these features. The feature extraction component also incorporates a data visualization module that displays the features overlaid on the model grid.

The CFD Assistant gives test engineers the capability to produce numeric simulations of wind tunnel runs while the wind tunnel test is still in progress. Any insights gained by comparing tunnel data with computational models can thus be applied to improving and fine-tuning further collection of data during the test. The DARWIN Workspace environment is designed to provide the aerospace customer of the future with the necessary information access to greatly improve the design cycle process by gleaning more knowledge from available data and thus providing the capability to perform true design cycle iterations in a single test entry.

Conclusions

The DARWIN IPT has created a robust model for remote access to aeronautics tests. Upon DARWIN's completion at the end of the 12-Foot Wind Tunnel High Wing Transport test at Ames Research Center, complete responsibility for the continued operation of the DReAM system will be handed off to the wind tunnel support organizations. Development for the next generation of the remote access system will continue, though under what guise or title is as yet unknown.

Acknowledgments

Special thanks goes to Mr. John Schreiner for his invaluable insights and suggestions. To all the DARWIN team we give great thanks as well. Updated information on the DARWIN program can be found at the

http://www.darwin.arc.nasa.gov/

world wide web site.

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